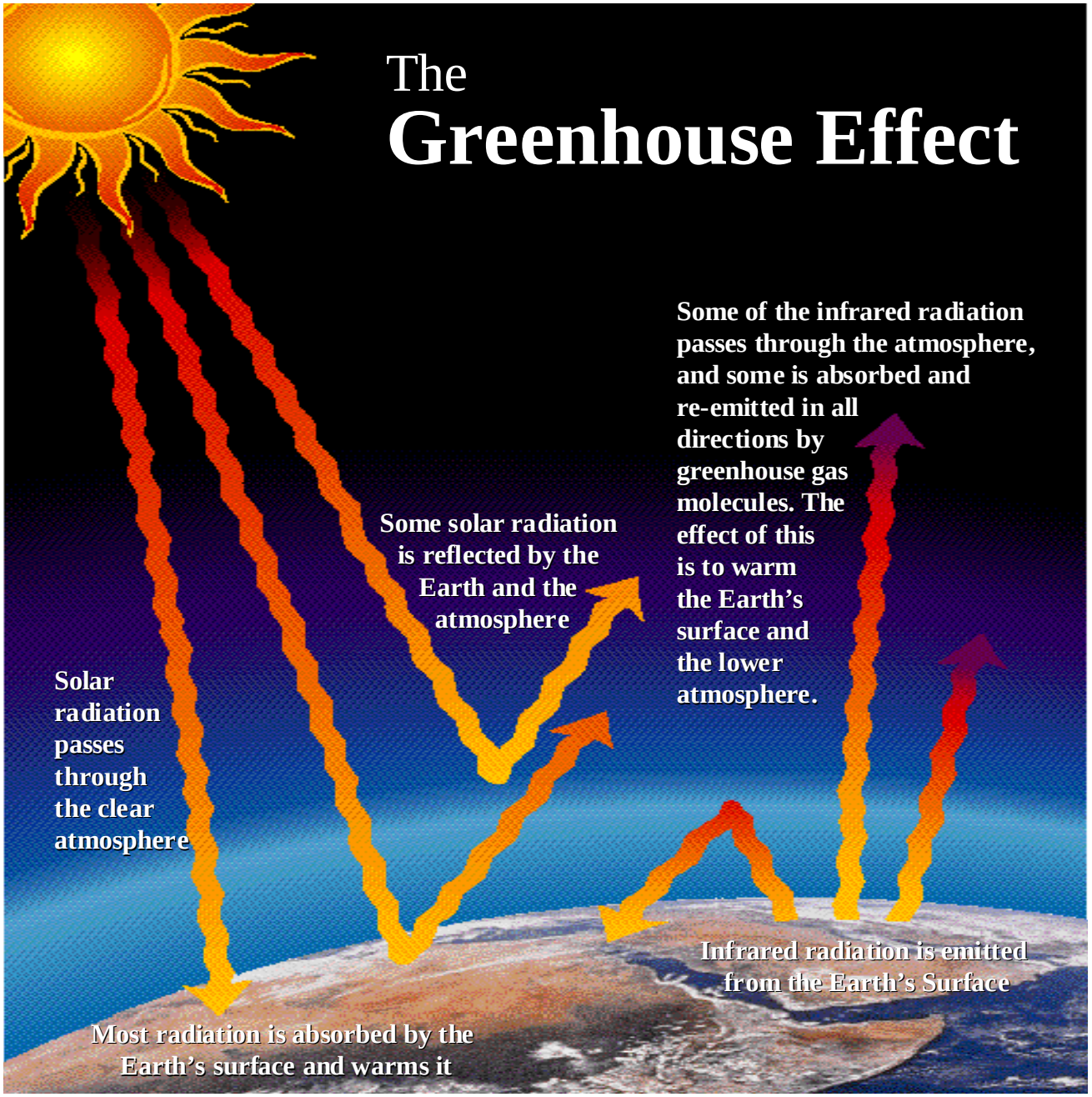
The Greenhouse Effect

- There is a natural greenhouse effect which keeps the Earth warm enough (average temperature about 60^{o}F) to be habitable
  - Greenhouse gases like carbon dioxide, methane, and nitrous oxide and water vapor trap heat and warm the earth's surface
- The basic principles of the greenhouse effect are well understood
- For a given concentration of greenhouse gases, the resulting amount of radiative forcing (or heat trapping of energy) can be predicted with precision
- Exactly how the Earth's climate will respond to enhanced greenhouse gases will also depend on complex interactions between the atmosphere, oceans, land, ice, and biosphere


The
Greenhouse Effect
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Some solar radiation is reflected by the Earth and the atmosphere
Solar radiation passes through the clear atmosphere
Infrared radiation is emitted from the Earth's Surface
Most radiation is absorbed by the Earth's surface and warms it

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Atmospheric Concentrations of Greenhouse Gases are Increasing

- Atmospheric concentrations of greenhouse gases have increased significantly since industrial revolution
  - Carbon dioxide +30%; Methane +100%; Nitrous oxide +15%
  - Greenhouse gas concentrations projected to reach double pre-industrial levels by about 2060
- Many greenhouse gases remain in atmosphere for a long time (decades to centuries)
- Projected CO_2 concentration levels are significantly higher than any observed over the past 160,000 years

Examples of Greenhouse Gases Affected by Human Activities

	CO_2	CH_4	N_2O
Pre-industrial concentration	280 ppmv	700 ppbv	275 ppbv
Concentration in 1994	358 ppmv	1720 ppbv	312 ppbv[2]
Rate of concentration change[1]	1.5 ppmv/yr	10 ppbv/yr	0.8 ppbv/yr
Atmospheric lifetime (years)	50-200[a]	12[b]	120

ppmv = part per million volume; ppbv = part per billion volume

[1] The growth rates of CO_2, CH_4 and N_2O are averaged over the decade beginning in 1984.

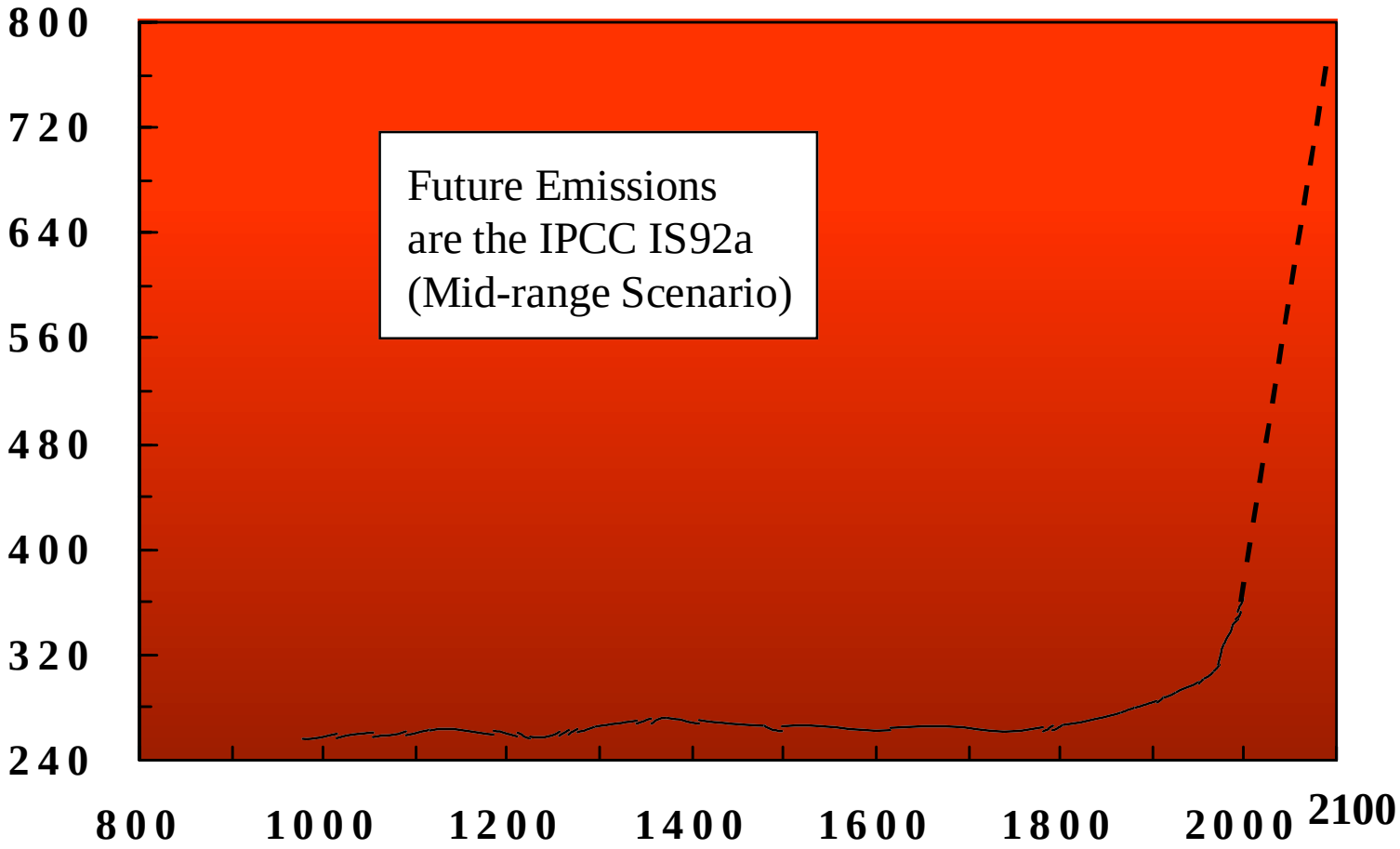
[2] Estimated from 1992-1993 data.

[a] No single lifetime for CO2 can be defined because of the different rates of uptake by different processes.

[b] Defined as an adjustment time which takes into account the indirect effects of methane on its own lifetime.

Source: IPCC, 1995

Historical and Projected Future CO_2 Concentrations



Derived from ice-core measurements (Siple and South Pole) and direct observation (Mauna Loa, Hawaii)
Source: Based on IPCC (1995)

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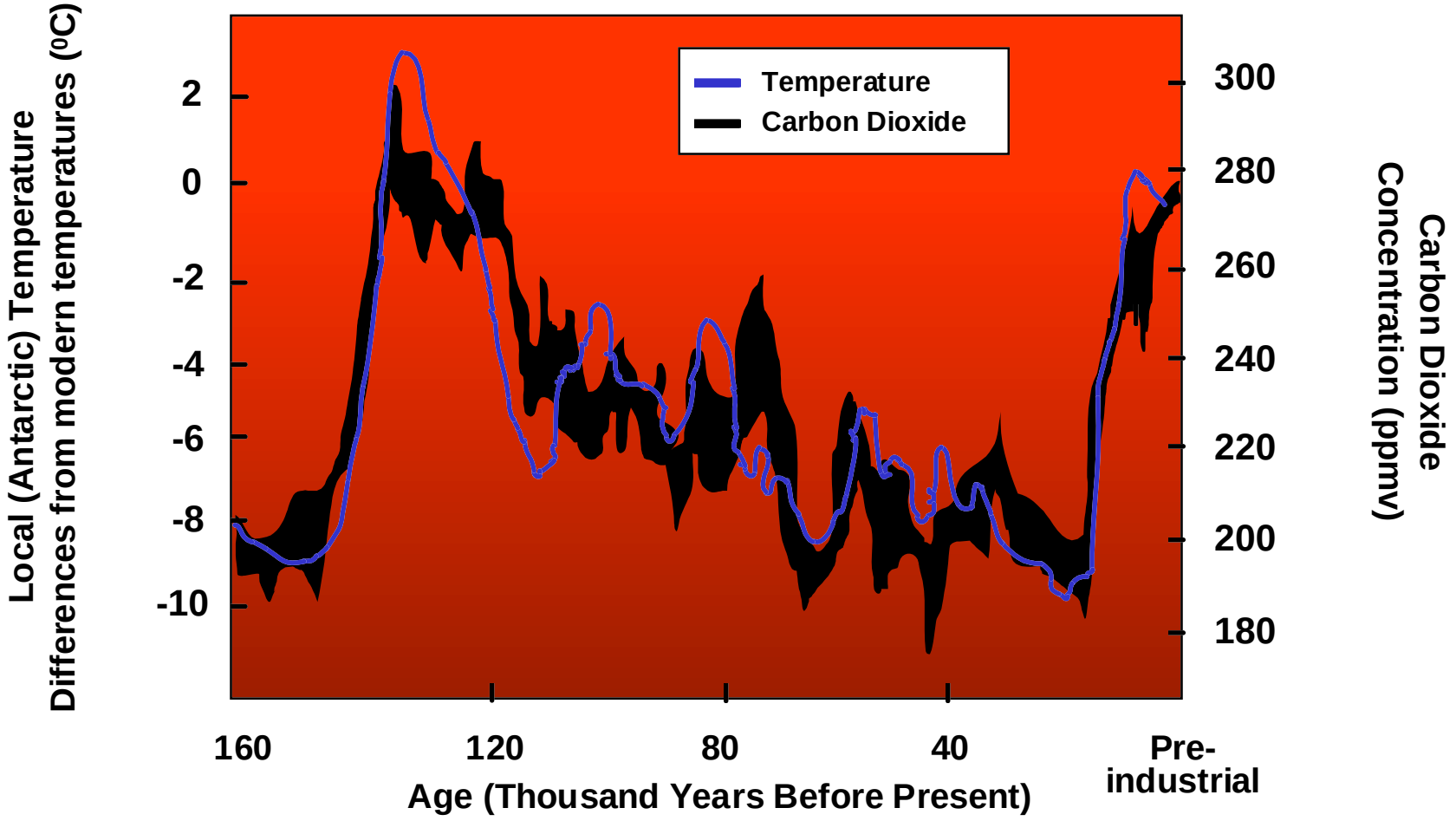
Local Temperature Change and CO_2 Concentrations Over the Past 160,000 Years



Derived from Antarctic ice cores

Source: Based on IPCC (1990)

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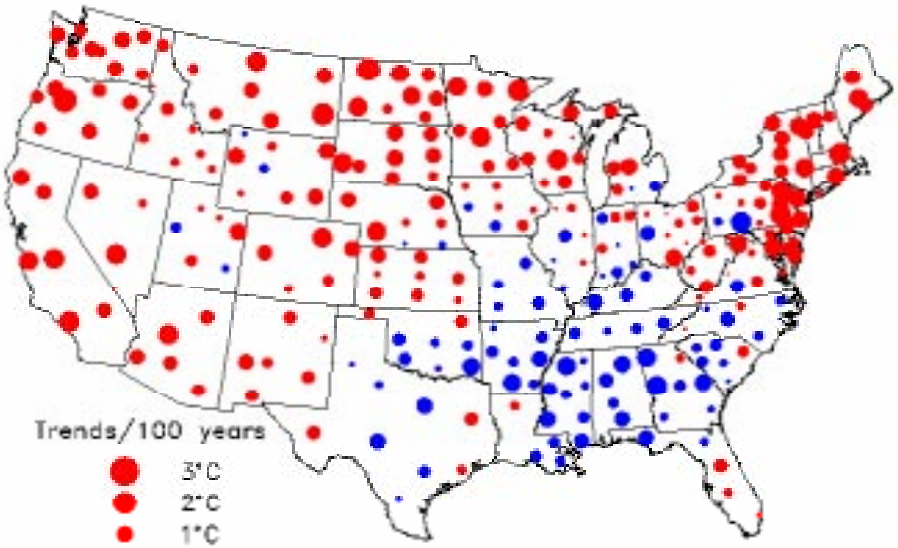
United States Environmental Protection Agency

Climate has Changed, and Will Continue to Change

- Climate has changed over the past century
  - Global mean temperature has increased .5-1^{o} F
  - Global sea level has risen 4-10 inches
  - Global precipitation over land has increased 1%
- "The balance of evidence suggests a discernible human influence on global climate" (IPCC, 1995)
- Climate is expected to continue to change in the future
  - Projected temperature increase of 3.6^{o}F by 2100 (1.8-6.3^{o}F)
  - Projected sea level rise of 20 inches by 2100 (6-38 inches)
  - Likely increase in precipitation intensity

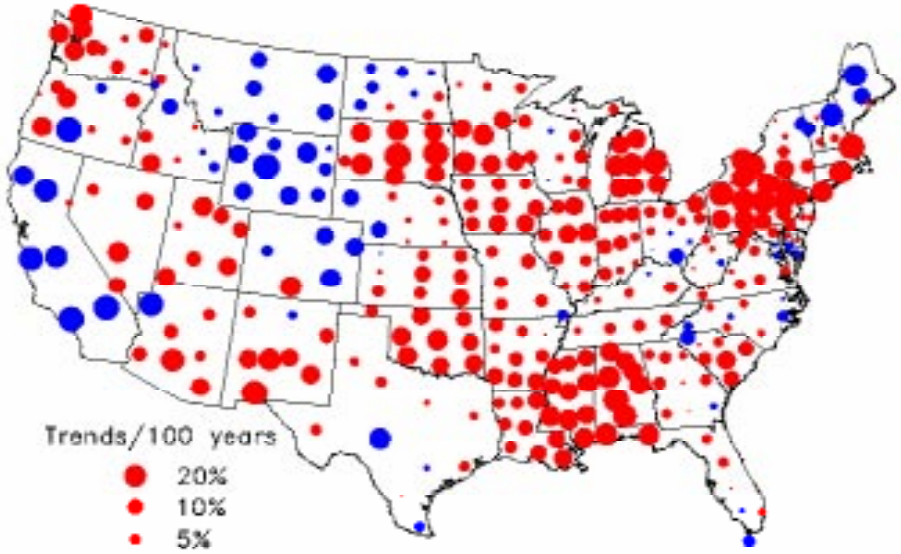
Temperature and Precipitation Trends, 1900 to Present

Temperature



Red circles reflect warming;
Blue circles reflect cooling

Precipitation



Red circles reflect increasing precipitation;
Blue circles reflect decreasing precipitation

Note: Cooling in southeast U.S. may be due to sulfate aerosol influence

Source: Karl et al. (1996)